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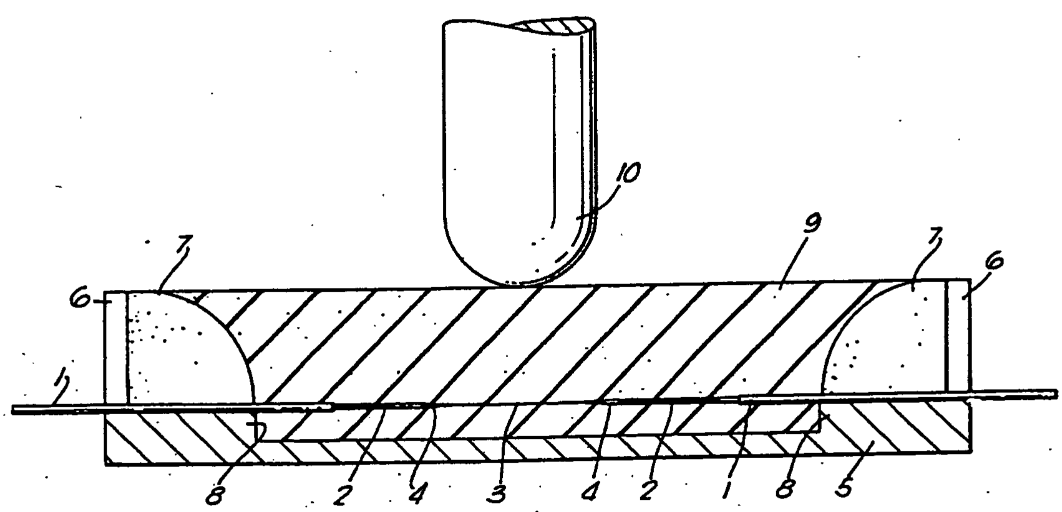
(54) Adjustable single-mode optical-fibre attenuator

(57) A single-mode optical-fibre attenuator is constituted by a straight length of single-mode fibre (1) with a reduced-diameter drawn-down portion (3) of high bend-loss sensitivity. This is embedded in a resilient medium such as a silicone resin (9) contained in a rigid box (5). Local elastic deformation of the surface of the silicone resin (9), as by a plunger (10), produces an elastic deformation (via a bend) of the embedded fibre thereby providing switchable attenuation in a length of fibre which previously exhibited low insertion loss. The resin (9) has a lower refractive index than the fibre and the deformation attenuates core modes by providing coupling to cladding modes.

Fig. 1.



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The drawing(s) originally filed were informal and the print here reproduced is taken from a later formal copy.

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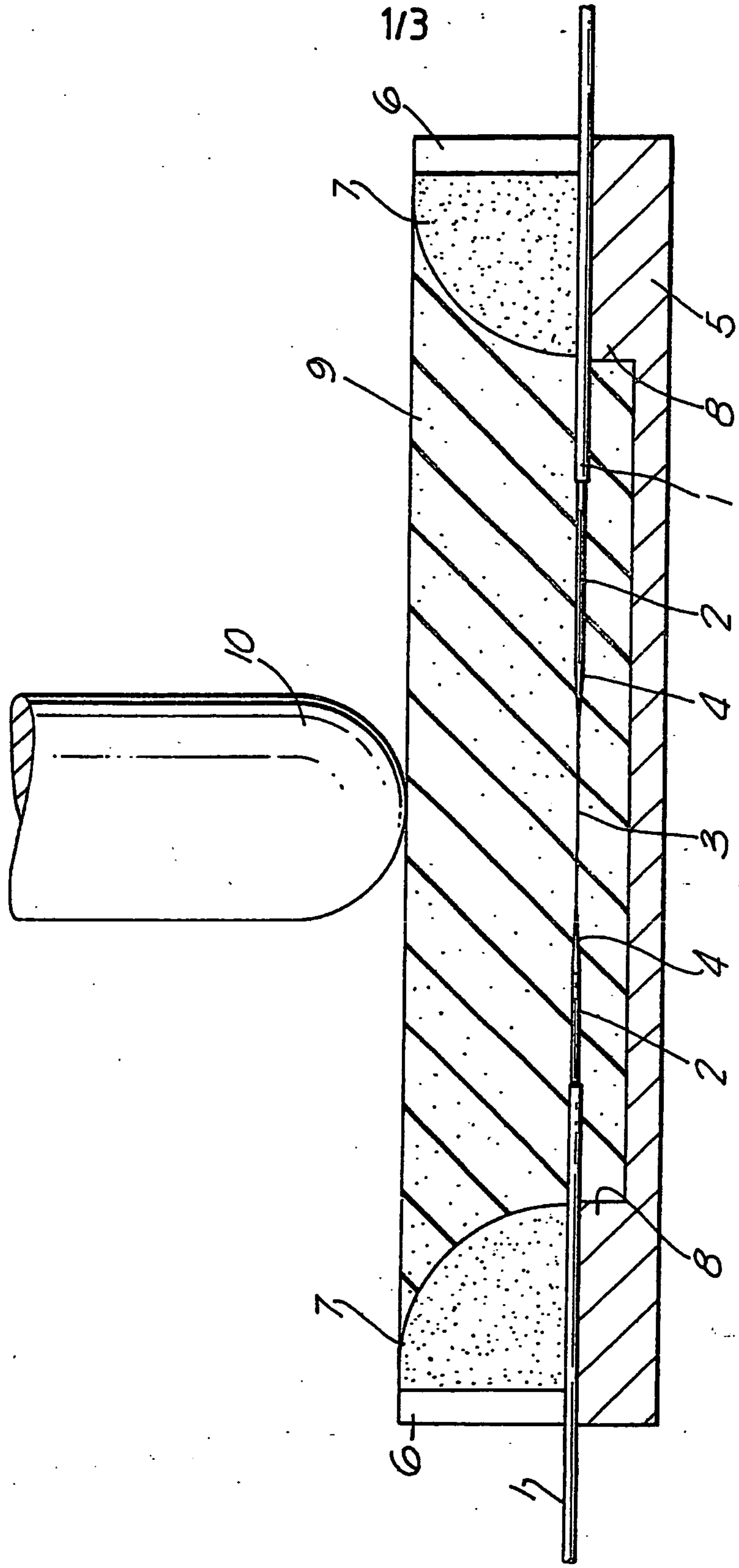

Fig.1.

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Fig. 2. 2/3

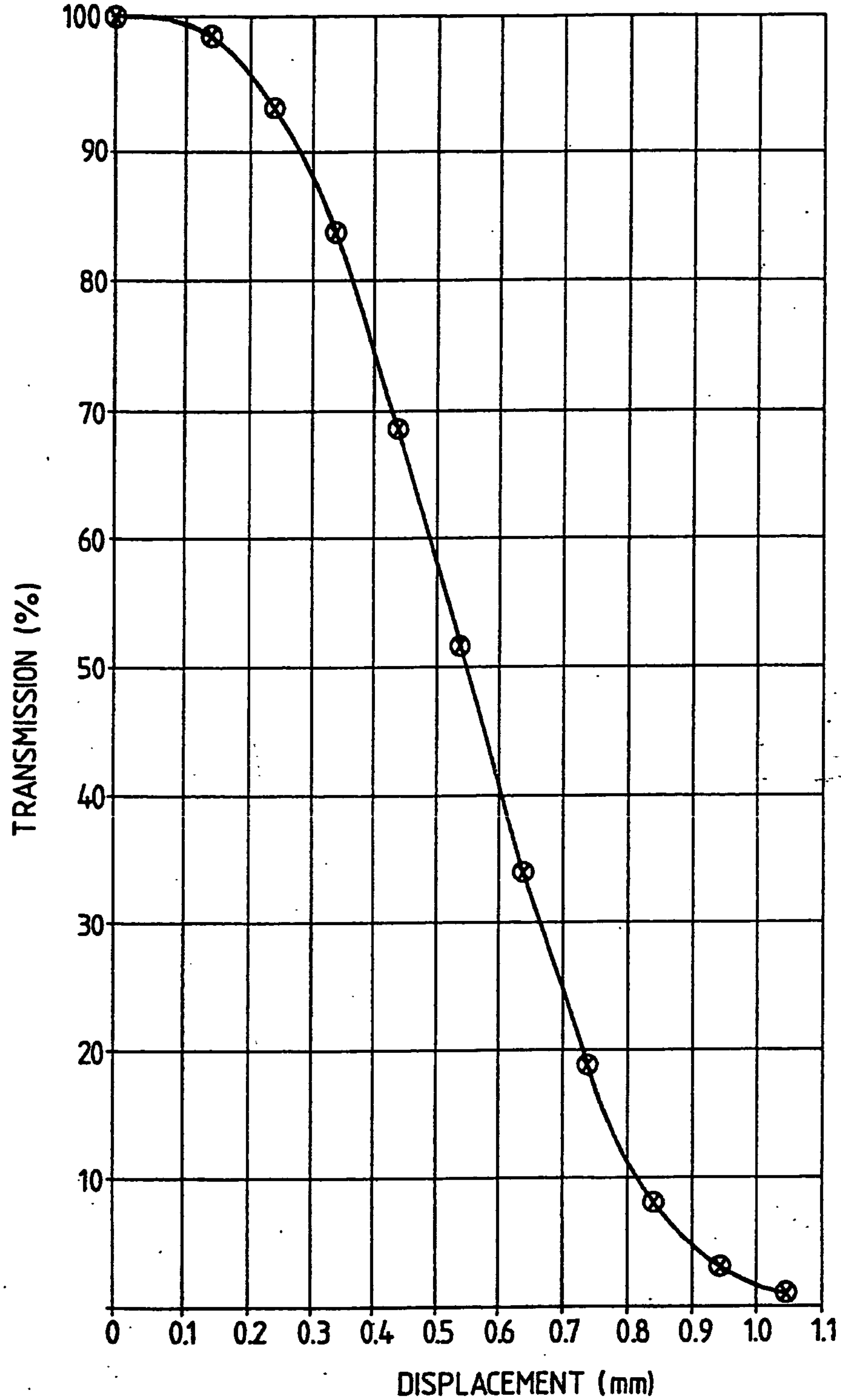

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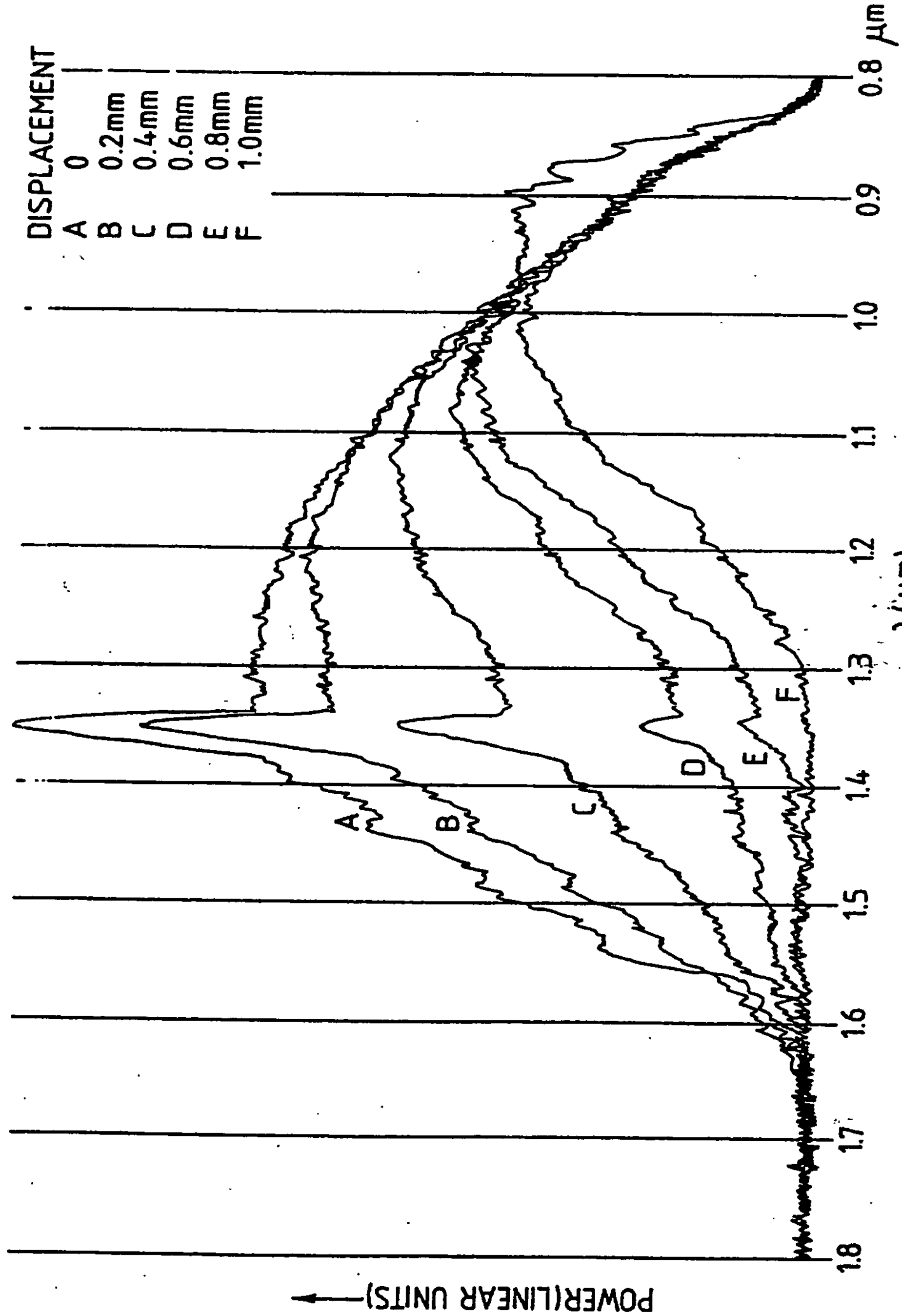
Fig. 3.



SPECIFICATION

Adjustable single mode optical fibre attenuator

Single mode optical fibre transmission systems require a series of fault location techniques to enable automatic isolation of a failure. To enable a fault in a transmitter, a receiver, or a length of cable, to be identified a switchable optical link is often required. This can be achieved by switching the output of a transmitter to the input of a receiver in the same terminal, but this requires the use of a low insertion loss high reliability single mode switch. The present invention is concerned with the provision of an adjustable single mode optical fibre attenuator which can be used as a component of such a switch and whose construction is such that the optical path is an uninterrupted all-fibre path from input to output of the attenuator through a single piece of optical fibre.

According to the present invention there is provided an adjustable single mode optical fibre attenuator, which attenuator includes a substantially straight length of single mode optical fibre having a reduced diameter portion of increased bend loss sensitivity intermediate its ends which length is embedded in a resilient medium contained in a rigid supporting structure, which attenuator further includes means for locally deforming the surface of the resilient medium thereby to introduce a bend into the reduced diameter portion of the fibre so as to increase the optical attenuation of the fibre. In such an attenuator the desired value of optical attenuation is realised by bend induced loss.

There follows a description of an attenuator embodying the present invention in a preferred form. This particular attenuator is for an application that requires the attenuation to be varied over a range of not more than 20 dB. The description refers to the accompanying drawings in which:

Figure 1 depicts a longitudinal section through the structure.

Figure 2 is a graph of attenuator transmission plotted as a function of displacement of a plunger, and

Figure 3 is a graph illustrating the wavelength dependent operation of the attenuator.

Referring to the drawing, a length 1 of plastics protective coated glass single mode optical fibre has a section of its plastics coating removed to expose bare fibre 2 which is provided with a reduced diameter portion 3 by stretching it while it is in a heat softened state. This reduced diameter portion is conveniently produced in a controlled manner, with adiabatic tapers 4 at each end, using the apparatus described in Patent Specification No. 2150703A that was designed for the manufacture of single mode fibre directional couplers. In the manufacture of a directional coupler this apparatus is used to produce progressive stretching of two or more fibres in side-by-side contact by traversing them longitudinally through a flame. Controlled stretching, and hence controlled reduction in diameter, is produced by clamping the fibre at two separate points in its length and arranging, for each traverse, for the leading clamp to be traversed at a slightly faster rate than the trailing clamp. The production of the reduced diameter portion of fibre for this attenuator proceeds in substantially same way, but in this instance only a single fibre is stretched instead of a side-by-side assembly of two or more fibres. By this means a relatively precisely controlled profile may be obtained, and in particular it may be ensured that the tapers 4 at either end of the portion 3 of reduced diameter are sufficiently gradual to be adiabatic (i.e. sufficiently gradual not themselves to introduce mode conversion).

A rigid box 5 is provided with a slot in each end wall 6 to allow the fibre 1 to extend through the box in a straight line. Adjacent the end walls the fibre is secured by fillets 7 of adhesive to internal shoulders 8 which maintain the reduced diameter portion of bar fibre a predetermined height above the base of the box. The interior of the box is then filled with a resilient medium 9 such as a silicone resin.

The optical attenuation presented by the fibre 1 is low all the time that that part of the fibre extending within the box 5 remains straight, particularly the portion 3 of reduced diameter. This portion is locally deformed by locally deforming the surface of the resin 9 within the radiussed end of a plunger 10. Movement of the plunger may be accomplished by any one of many different methods including operation with a mechanical lever, micrometer adjustment, and, for remote operation, solenoid actuation.

A particular example of attenuator was made with vapour deposited silica fibre desinged for single mode operation at a wavelength of 1300 nm. This fibre had a doped silica core and an undoped cladding of 125 microns o.d. Its Gaussian spot diameter was 10.5 microns and its equivalent step index parameters were a 9 microns core diameter for an index difference of 0.0033. Using the above referenced stretching technique a reduced diameter portion about 40 microns in diameter, and about 8 to 10 mm in length, was prepared and incorporated into an attenuator as described above with reference to Fig. 1. The box was dimensioned so that the shoulders held the fibre 1 mm above the base of the box, and the resin filled the box to a height 4 mm above the fibre. Fig. 2 shows how, at a wavelength of 1300 nm, the transmission of the attenuator changed as the reduced diameter portion of the fibre was pro-

gressively deflected by forcing a plunger with a 6.35 mm diameter spherical end progressively deeper into the top surface of the resin. The resin has a lower refractive index than the silicon of the fibre, and hence the deformation attenuates the core mode by converting a proportion of its power into cladding modes supported by the interface between the fibre and the resin. To obtain a measure of the core mode attenuation provided by the attenuator it is therefore necessary to ensure that cladding mode light is not able to reach the detector. To this end measurements were made using the series combination of a spectrally broad emission source, a monochrometer, the attenuator, a mode stripper, and a detector.

No measurable hysterisis in the transmission curve was observed when the plunger was progressively retracted from the resin, and this same curve was found to be traced out a number of times without observable change when the attenuator was subjected to a repeated cycle of plunger displacements. From the curve of Fig. 2 it is seen that a displacement of 1.04 mm in the top surface of the resin produced, at a wavelength of 1300 nm, a 20 dB increase in attenuation presented by the fibre. The effect of varying the plane of polarisation of the light launched into the fibre when making attenuation measurements were investigated and a variation of $\pm\frac{1}{4}$ dB was found at the 10 dB point, and $\pm\frac{1}{2}$ dB at the 20 dB point. The wavelength dependence of the attenuator was also investigated, and in Fig. 3 there is shown, for various settings of displacement of the plunger, the response of the photodetector as a function of wavelength transmitted by the monochromater. This figure shows the expected progressive displacement of the bend loss edge towards shorter wavelengths as the fibre deformation is increased.

Previous reference has been made to the fact that the attenuation is produced when deformation of the fibre causes coupling between the core mode and the cladding modes. An estimate of the likely maximum attenuation achievable by this means may be derived by calculating the number of modes that can be supported by the cladding, and by making the assumption that the mode coupling is effective in sharing the power substantially equally between all modes. Assuming that the refractive index of the resin is 1.405, and given that the number of modes supported by a step index structure of 'V'-value V is $V^2/2$, it can be shown that the reduced diameter portion of the fibre is capable of supporting approximately 600 cladding modes. Under the assumption that power is shared equally between the modes, and remembering that the fundamental core mode is degenerate, it can be seen that the maximum attenuation achievable by this attenuator is likely to be in the region of 25 dB. If requ[illegible] this value can in principle be improved u[illegible]n a number of ways. One way is to attenuate the cladding modes in the reduced diameter portion of the fibre, for instance, by embedding it in an absorbing resin rather than a transparent one. Another way is to prevent the formation of cladding modes in the first instance by arranging for the fibre to be embedded in a resin of greater refractive index than that of the fibre. A third method is to retain the cladding modes supporting structure, but loop the fibre back through the box and provide a second portion of reduced diameter fibre to be located alongside the first. Provided that the loop between the two reduced diameter portions naturally attenuates cladding modes, or incorporates specific means to attenuate them, this arrangement effectively provides two regions of variable attenuation optically in series but mechanically ganged.

CLAIMS

1. An adjustable single mode optical fibre attenuator, which attenuator includes a substantially straight length of single mode optical fibre having a reduced diameter portion of increased bend loss sensitivity intermediate its ends which length is embedded in a resilient medium contained in a rigid supporting structure, which attenuator further includes means for locally deforming the surface of the resilient medium thereby to introduce a bend into the reduced diameter portion of the fibre so as to increase the optical attenuation of the fibre.

2. An attenuator as claimed in claim 1, wherein the nature of the interface between the reduced diameter portion of the fibre and the resilient medium in which it is embedded is such as not to support cladding modes or is such as to provide attenuation of cladding modes.

3. An attenuator as claimed in claim 1, wherein said straight length of single mode fibre is integrally connected by a loop of fibre with a second straight length of single mode fibre having a reduced diameter portion embedded in the resilient medium alongside that of the first-mentioned straight length of fibre.

4. An attenuator substantially as hereinbefore described with reference to the accompanying drawings.

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